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PERFORMANCE OF CURVED ORGANIC PHOTOVOLTAICS MODULES FOR MEMBRANES INTEGRATION: SOLAR SIMULATION TESTS

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Summary:

Photovoltaic (PV) solar technology is considered among the best product renewable energy sources for building applications. Flexible thin-film technology has potentials not only for traditional architectures, but also the most innovative applications that favor envelopes characterized by free morphologies such as membrane structures. Integrating flexible solar modules in pre-tensioned membrane structures allows for wide design varieties of shapes and geometries. However, the fact that curved and inclined PV modules whose orientation is guided by the membrane roof surface receive inhomogeneous radiation intensities across the module makes it necessary to measure the I-V characteristics in a testing environment to calculate the overall modules performance. This paper will be dedicated to investigating the yield of Organic Photovoltaics Modules and how the integration of organic flexible PV module onto a curved membrane surface has an impact on the PV module's output in a solar simulation test environment.

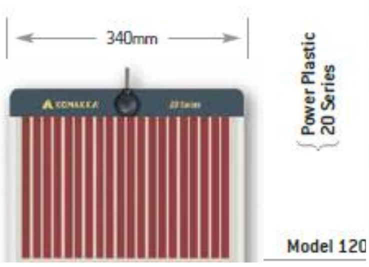
1 INTRODUCTION

The wide application of ETFE into architecture and the material characteristics starting from its lightweight, transparency, flexibility and ending with the sustainability and the durability make it a recommended substrate for the cheapest pv technology, Organic Photovoltaics. Although the OPV's efficiency is still low compared to the first and the second PV generations but this integration between the ETFE and OPV should represent a more cost-effective solution for the creation of a new kind of facade employable both in existing and new construction. Moreover, as Organic PV cells is mainly manufactured from polymers which is responsible for the module translucensy unlike common Silicon PV technologies, this makes OPV's are the best candidate when integrated with transparent ETFE cushions for maximizing the daylighting performance of building envelopes.

The integration of Flexible Photovoltaic Technology into membrane structures offers a promising significant step in the market development. However, some challenges and questions are arising relating to the applicability of such systems and how they are significantly dependant on a list of complex aspects that should be considered during the design phase. Among those aspects: I. Estimating the yield of PV system attached to membrane geometries whom surfaces are characterised by single or double curvature is a complex process. II. The distribution of stresses and deflection over the membrane surface and their impact on PV modules arrangement. III. The optimum orientation of PV modules to solar radiation in the determined geographic zone. IIII. The complex forms for membranes make it difficult to follow the areas under shadowing effect that should be avoided for locating modules.

2 ORGANIC PV SOLAR SIMULATION TESTS

The tests are conducted at the laboratory of General Electric Global Research Centre in Munchen, Germany using photovoltaics modules of Konarka power plastic lightweight thin-film organic solar module, Model 540 and 120 as shown in Fig.1, 2& 3. The target of these tests is to investigate how the integration of organic flexible PV module onto a curved membrane surface has an impact on the PV module's output. The fact that curved and inclined PV modules whose orientation is guided by the membrane roof surface receive inhomogeneous radiation intensities across the module makes it necessary to measure the I-V characteristics in a testing environment to calculate the overall modules performance. This part of the research will be dedicated to investigating the yield of Organic Photovoltaics Modules in relation to curvature in a solar simulation test environment.

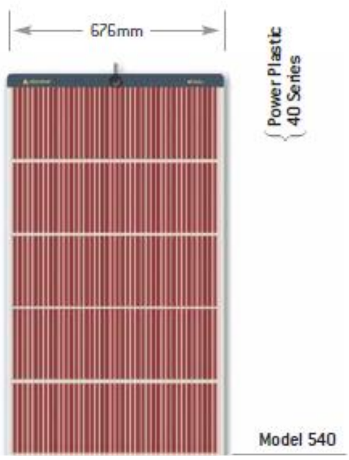


Fig.1, Fig.2. & Fig.3: Konarka OPV modules (Konarka power plastic)

2.1. Test Setup

The test facility at the laboratory of GE composes of a solar simulator of 6 metal-halide lamps arranged in two rows. Each lamp can be adapted to a range of radiation values starting from 400 to 1200 W/M². A PVPM Meter (PVPM1000C40) device is connected to the module to measure the I-V characteristics of the modules using PVPM Display software. A Radiation sensor is located at the level of PV surface and transfer the measured values to the PVPM meter. A temperature sensor is connected to the backside of the module surface to monitor the temperature. Fig.4. indicates a model of the test facility.

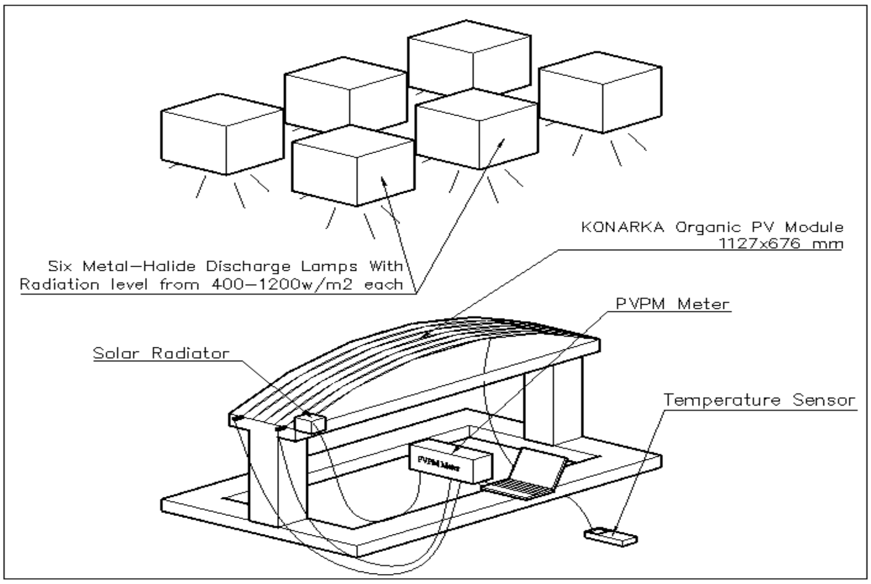


Fig.4. : The test stand and Equipments

2.2. Testing the Exact Performance Values

The first tests were done to measure the modules actual performance using the FLASHER equipment as shown in Fig.5. The target was to assess the modules technical values provided by the manufacturer's datasheet. The modules output was measured for the two 120 and 540 modules types. The obtained measurements are as follow:

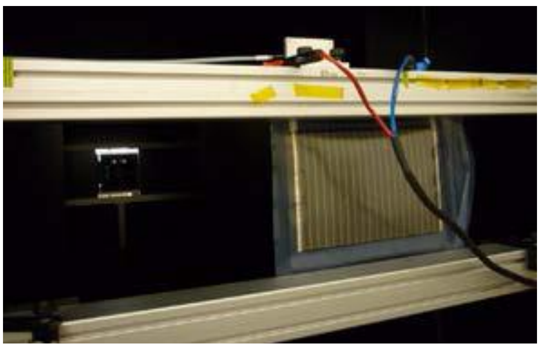


Fig.5: Measuring the modules output by a Flasher device

Module Type	Irradiance w/m^2	Isc (A)	Voc (V)	MPP (W)	Efficiency (%)
Power Plastic 540	1000	0.96	23.2	12	1.6
Power Plastic 120	1000	0.2	11.63	1.18	1.3

Table 1: The exact performance values of Konarka OPV modules

2.3. Testing the Dependency of Curvature from Efficiency

Test Description: These tests are dedicated to monitoring the modules performance in relation to their curvature. A module's performance of Power Plastic 540 is tested in six different curved positions starting from the flat zero curvature position till 9% curvature, as shown in Fig. 6. The GE laboratory test facility allows setting the module at different curvatures by fixing them on metal bars that could be clamped at their ends from both sides by controlling the distance "R" thus the curvature desired. See Fig.6, 7&8.

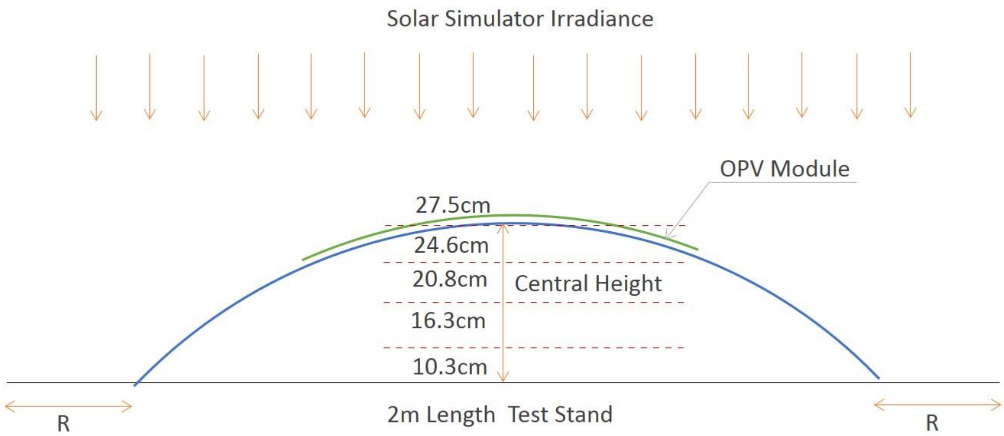


Fig.6: Testing stand

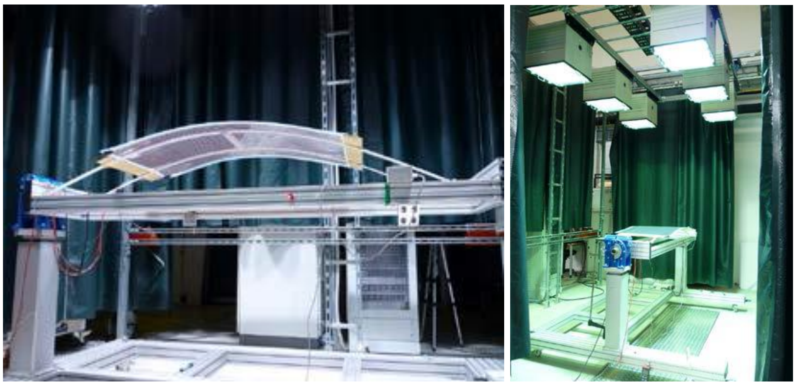


Fig.7 & Fig.8.: Testing the modules performance under curved positions

The module's output in the flat position resulted in 9.2W while the performance has decreased to 9.1, 9.0, 8.9, 8.7 and 8.6 W corresponding to 3%, 5%, 7%, 8% and 9% respectively as indicated in Table:2.

Module Type	Voc (V)	Isc (A)	MPP (W)	T Mod	Irradiance w/m^2	Central Height (cm)
Flat Position	21.97	0.7	9.2	51.8	699	0
3% Curvature	21.88	0.6	9.1	42.4	352	10.3
5% Curvature	21.91	0.6	9.0	41.8	340	16.3
7% Curvature	21.91	0.6	8.9	42.3	330	20.8
8% Curvature	21.90	0.6	8.7	43.3	342	24.6
9% Curvature	21.90	0.6	8.6	55.2	326	27.7

Table 2: The modules output at curved positions

2.4. Analysis of Measurements:

The first results showed that the performance of modules increase with increasing the curvature which seemed irrational as the flatter surfaces should receive the maximum radiation quantity and thus produce the higher output. The reason behind that the more curvature the module has the less distance between the module and the radiation source becomes. This is unlike the real conditions where the sun is far from earth by millions of kilometers. Therefore, an adjustment to the test setting was made by keeping the distance between the module peak point and the laps fixed by lowering the whole test structure by the same distance of the module rise resulted from increased curvature. Fig.9 indicates the results after the performed correction and show that the flatter the solar module is the higher performance the module achieves.

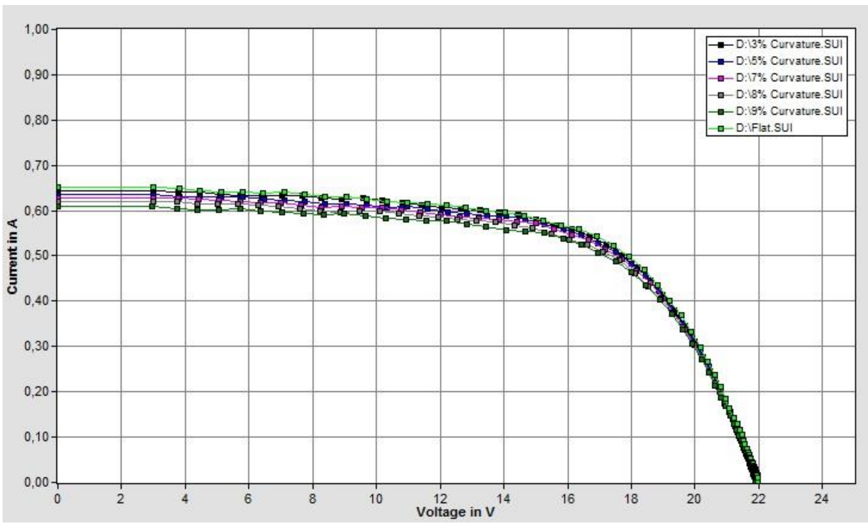


Fig.9: Indicates the I-V output for different curvatures of Konarka 540 module

3 CONCLUSION

The tests showed that Organic PV resulted in good performance rates when applied to curved surfaces. The yield of the modules decrease with increasing curvature and inclination as they receive less amount of perpendicular radiation to their plane. For an optimum performance, modules should be flat. Moreover, a comparison between Organic modules and Amorphous silicon is performed to calculate the rate of performance loss for both technologies. The Amorphous Silicon Tests Results is a part of Masters dissertation by Lakatos, 2011 in which he conducted his research using the same testing settings and thus the results can be comparable. The first and last reading for flat and 9% curvature were excluded from the comparison because of the inhomogeneous radiation value. The study showed that for the organic modules, a performance value of 0.028 Watt is reduced every 1cm increasing of central height. Whereas for Amorphous sislicon modules, the reducted value is 0.03 Watt/1cm [3]. This comparison shows that both technologies have similar behavior in this aspect and that OPV has good potentials to compete with other PV technologies.

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